Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L6	1	("5259924").PN.	US-PGPUB; USPAT	OR	OFF	2005/08/11 08:38
L7	2292	(silicon adj nitride) and ((etching or removing or etch or etched) with substrate) and (resist or mask or photoresist)	USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/08/11 08:40
L8	951	7 and ((trench or opening or recess or aperture or depression or hole) with substrate)	USOCR; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2005/08/11 08:44
L9	35923	(silicon adj nitride) and ((etching or removing or etch or etched) with substrate) and (resist or mask or photoresist)	US-PGPUB; USPAT	OR	ON	2005/08/11 09:19
L10	23376	9 and ((trench or opening or recess or aperture or depression or hole) with substrate)	US-PGPUB; USPAT	OR	ON	2005/08/11 09:19
L11	23376	10 and (silicon or polysilicon)	US-PGPUB; USPAT	OR	ON	2005/08/11 09:20
L12	17305	11 and @ad<"20021030"	US-PGPUB; USPAT	OR	ON	2005/08/11 09:21
L13	17305	12 and (nitride with (silicon or polysilicon))	US-PGPUB; USPAT	OR	ON	2005/08/11 09:22
L15	15552	13 and mask	US-PGPUB; USPAT	OR	ON	2005/08/11 09:23
L16	5503	13 and ((etch or etching) with mask with (polisilicon or silicon))	US-PGPUB; USPAT	OR	ON	2005/08/11 09:26

	Type	L #	Hits	Search Text	DBs	Time Stamp
1	IS&R	L6	1	("5259924").PN.	US-PGPUB; USPAT	2005/08/11 08:38
2	BRS	L7	2292	(silicon adj nitride) and ((etching or removing or etch or etched) with substrate) and (resist or mask or photoresist)	USOCR; EPO; JPO; DERWENT; IBM_TDB	2005/08/11 08:40
3	BRS	L8	951	7 and ((trench or opening or recess or aperture or depression or hole) with substrate)	USOCR; EPO; JPO; DERWENT; IBM_TDB	2005/08/11 08:44
4	BRS	L9	35923	(silicon adj nitride) and ((etching or removing or etch or etched) with substrate) and (resist or mask or photoresist)	US-PGPUB; USPAT	2005/08/11 09:19
5	BRS	L10	23376	9 and ((trench or opening or recess or aperture or depression or hole) with substrate)	US-PGPUB; USPAT	2005/08/11 09:19
6	BRS	L11	23376	10 and (silicon or polysilicon)	US-PGPUB; USPAT	2005/08/11 09:20
7	BRS	L12	17305	11 and @ad<"20021030"	US-PGPUB; USPAT	2005/08/11 09:21
8	BRS	L13	17305	12 and (nitride with (silicon or polysilicon))	US-PGPUB; USPAT	2005/08/11 09:22
9	BRS	L15	15552	13 and mask	US-PGPUB; USPAT	2005/08/11 09:23
10	BRS	L16	5503	13 and ((etch or etching) with mask with (polisilicon or silicon))	US-PGPUB; USPAT	2005/08/11 09:26

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	2140	438/221,296,424.ccls.	US-PGPUB; USPAT	OR	ON	2005/08/11 13:26
L2	1672	1 and @ad<"20021030"	US-PGPUB; USPAT	OR	ON	2005/08/11 13:26
L3	1185	2 and (silicon adj nitride)	US-PGPUB; USPAT	OR	ON	2005/08/11 13:26
L4	1430	257/510,506.ccls.	US-PGPUB; USPAT	OR	ON	2005/08/11 13:26
L5	1124	4 and @ad<"20021030"	US-PGPUB; USPAT	OR	ON	2005/08/11 13:26
L6	676	5 and (silicon adj nitride)	US-PGPUB; USPAT	OR	ON	2005/08/11 13:26
L7	554	6 not 3	US-PGPUB; USPAT	OR	ON	2005/08/11 13:26

US-PAT-NO: 6333232

DOCUMENT-IDENTIFIER: US 6333232 B1

TITLE: Semiconductor device and method of manufacturing the same

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Abstract Text - ABTX (1):

Before forming a trench in a silicon substrate through a patterned **silicon nitride film serving as a mask, etching** is executed until the main surface of the silicon substrate is exposed. Thereafter exposed side walls of a silicon dioxide film and a polysilicon film and the exposed surface of the silicon substrate are oxynitrided thereby forming an silicon oxynitride film. Thereafter the trench is formed, then a silicon dioxide film is formed on its inner wall, and thereafter the trench is filled with an insulation. In the process of forming the silicon dioxide film on the inner wall, a bird's beak is formed on the side walls of the silicon dioxide film and the polysilicon film. The silicon oxynitride film suppresses excessive growth of the bird's beak and prevents the bird's beak from formation of a depressed part. Thus, reduction of the area of an active region caused by the bird's beak is suppressed without no depression part formed on the upper end of an STI structure.

Brief Summary Text - BSTX (10):

The STI structure is an element isolation structure essentially free from a bird's beak, i.e., involving no bird's beak. In the STI structure free from a bird's beak, however, stress resulting from the shape of a trench forming the STI structure concentrates to a corner part (part between the bottom and the side wall) on the bottom of the trench or the upper end (i.e., **opening** end) of the trench, to result in formation of a defect in a silicon substrate. When a defect is formed around the trench, a leakage current is increased when the MOSFET is turned off, to remarkably increase power consumption of the semiconductor device.

Brief Summary Text - BSTX (12):

A series of steps of forming an STI structure including a step of forming a bird's beak are now described in detail. FIGS. 48 to 58 are step diagrams showing a conventional method of forming an STI structure. In order to form the STI structure, a silicon dioxide film 102, a polysilicon film 103 and a

silicon nitride film 104 are formed in this order on a silicon substrate 101, as shown in FIG. 48. The silicon dioxide film 102 is also referred to as an underlayer oxide film.

Brief Summary Text - BSTX (13):

The step shown in FIG. 49 is then carried out. In the step shown in FIG. 49, resist is applied onto the **silicon nitride** film 104 and thereafter patterned through a transfer step, for forming a resist mask 105. Thereafter the resist mask 105 is employed as a mask (screen) for executing anisotropic etching, thereby selectively removing the **silicon nitride** film 104. Since the ratio of the etching rates for the **silicon nitride** film 104 and the polysilicon film 103 is sufficiently large, the anisotropic etching stops on the upper surface of the polysilicon film 103. In this step, the resist mask 105 is also partially removed by the etching. If the quantity of this overetching is large, the resist mask 105 may be entirely removed.

Brief Summary Text - BSTX (14):

In the subsequent step shown in FIG. 50, the resist mask 105 is removed and thereafter anisotropic etching is executed through the patterned **silicon nitride film 104 employed as a hard mask,** thereby selectively **removing** the polysilicon film 103, the silicon dioxide film 102 and the silicon substrate 101 in this order. Needless to say, etchants employed for the anisotropic etching are properly changed following stepwise change of the films to be removed in this step. Through this step, a trench 106 of about 300 nm in depth, for example, is formed in the silicon substrate 101. In the anisotropic etching performed on the silicon substrate 101, the etching rate for polysilicon is larger than that for single-crystalline silicon. Therefore, the inner wall of the polysilicon film 103 slightly retreats through the step shown in FIG. 50.

Brief Summary Text - BSTX (17):

It is possible to assume a method of omitting the step of depositing the polysilicon film 103 and directly depositing the **silicon nitride** film 104 on the silicon dioxide film 102 in order to reduce the bird's beak length. In this case, however, stress caused on the upper end of the trench 108 is disadvantageously increased as compared with the case of providing the polysilicon film 103, depending on the conditions.

Brief Summary Text - BSTX (18):

Then, the trench 106 covered with the inner wall silicon dioxide film 107 is filled with silicon dioxide 109, for example, as shown in FIG. 52. This step is carried out by depositing the silicon dioxide 109 to cover the upper surface

of the **silicon nitride** film 104, the side surfaces of the **silicon nitride** film 104 and the polysilicon film 103, the side surface of the underlayer dioxide film 102 and the inner wall of the silicon substrate 101 by a film formation method such as HDP (high density plasma)-CVD (chemical vapor deposition), for example, simultaneously performing etching and film formation. The trench 107 may be basically filled with any insulation such as silicon dioxide, silicon oxynitride or TEOS, for example.

Brief Summary Text - BSTX (19):

Then, CMP (chemical mechanical polishing) is performed through the **silicon nitride** film 104 serving as a stopper thereby flattening the upper end of the silicon dioxide 109, as shown in FIG. 53. After this flattening step, the silicon dioxide 109 remains in the trench 106.

Brief Summary Text - BSTX (20):

Then, the **silicon nitride** film 104 and the polysilicon film 103 are removed by etching, as shown in FIG. 54.

Brief Summary Text - BSTX (33):

A semiconductor device according to a first aspect of the present invention has an element isolation structure separating a main surface of a semiconductor substrate into a plurality of regions selectively formed on the main surface and a semiconductor element formed on each of the plurality of regions, and the element isolation structure comprises an inner wall insulator film formed on an inner wall of a trench selectively formed in the main surface to include an oxide **semiconductor film** coming into contact with the inner wall and having a bird's beak, increased in thickness on an **opening** end of the trench, containing an oxynitride semiconductor, and an insulation filled into the trench through the inner wall insulator film.

Brief Summary Text - BSTX (37):

According to a third aspect of the present invention, another insulator film including a nitride **semiconductor film** is interposed between the insulator film and the insulation in the semiconductor device according to the first or second aspect.

Brief Summary Text - BSTX (38):

In the device according to the third aspect, the nitride **semiconductor film** is interposed between the insulator film and the insulation, whereby diffusion of an oxidant following thermal oxidation is suppressed in a manufacturing step to suppress oxidation on the interface between the semiconductor substrate and the element isolation structure. Therefore, the density of oxidation-induced

defects is suppressed.

Brief Summary Text - BSTX (39):

According to a fourth aspect of the present invention, another insulator film including an oxynitride **semiconductor film** is interposed between the insulator film and the insulation in the semiconductor device according to the first or second aspect.

Brief Summary Text - BSTX (40):

In the device according to the fourth aspect, the oxynitride **semiconductor film** is interposed between the insulator film and the insulation, whereby diffusion of an oxidant following thermal oxidation is suppressed in a manufacturing step to suppress oxidation on the interface between the semiconductor substrate and the element isolation structure. Therefore, the density of oxidation-induced defects is suppressed. Further, the coefficient of volumetric expansion of the oxynitride semiconductor is approximate to that of the semiconductor, whereby stress is further effectively relaxed.

Brief Summary Text - BSTX (41):

A semiconductor device according to a fifth aspect of the present invention has an element isolation structure separating a main surface of a semiconductor substrate into a plurality of regions selectively formed on the main surface and a semiconductor element formed on each of the plurality of regions, and the element isolation structure comprises an inner wall insulator film formed on an inner wall of a trench selectively formed in the main surface to include an oxide **semiconductor film** coming into contact with the inner wall and a nitride **semiconductor film** covering the same and having a bird's beak increased in thickness on an **opening** end of the trench and a fluorine-containing insulation filled into the trench through the inner wall insulator film.

Brief Summary Text - BSTX (42):

In the device according to the fifth aspect, the trench is filled with the fluorine-containing insulation, whereby the parasitic capacitance between the semiconductor elements isolated by the element isolation structure is reduced. Further, the nitride **semiconductor film** suppresses diffusion of an oxidant, thereby suppressing oxidation on the interface between the semiconductor substrate and the element isolation structure in thermal oxidation performed in a manufacturing step. Therefore, the density of oxidation-induced defects is suppressed.

Brief Summary Text - BSTX (43):

A method of manufacturing a semiconductor device according to a sixth aspect

of the present invention comprises steps of (a) preparing a semiconductor substrate having a main surface, (b) forming a multilayer film including an oxide **semiconductor film** and a nitride **semiconductor film** located thereon on the main surface of the semiconductor substrate, (c) patterning the nitride **semiconductor film** thereby selectively forming an **opening** having a shape separating the main surface into a plurality of regions in the nitride **semiconductor film,** (d) executing etching through the patterned **nitride semiconductor film employed as a mask** thereby selectively **removing** a portion immediately under the **opening** at least until the main surface of the semiconductor substrate is exposed, (e) oxynitriding a surface located under the nitride **semiconductor film** and exposed in a cavity formed immediately under the **opening,** (f) executing etching through the patterned **nitride semiconductor film employed as a mask** thereby forming a trench in a portion of the semiconductor substrate immediately under the **opening,** (g) forming an inner wall insulator film including an oxide **semiconductor film** coming into contact with an inner wall of the trench on the inner wall, (h) filling the trench with an insulation after the step (g), (i) **removing** the multilayer film at least after the step (g), and (j) forming a component of a semiconductor element in each of the plurality of regions separated from each other by the trench in the main surface of the semiconductor substrate.

Brief Summary Text - BSTX (44):

In the manufacturing method according to the sixth aspect, an oxynitride **semiconductor film** is formed on the side wall of a portion under the nitride **semiconductor film** of the multilayer film through the oxynitriding step, thereby suppressing diffusion of an oxidant on the side wall of the portion under the nitride **semiconductor film** of the multilayer film in the step of forming the inner wall insulator film. Thus, excessive growth of a bird's beak following formation of the inner wall insulator film can be suppressed, for suppressing reduction of an active region. At the same time, an oxynitride semiconductor part in the bird's beak is left unremoved in the step of removing the multilayer film, whereby no depressed part is formed despite the small thickness of the bird's beak.

Brief Summary Text - BSTX (45):

According to a seventh aspect of the present invention, the multilayer film further includes a polycrystalline **semiconductor film** held between the oxide **semiconductor film** and the nitride **semiconductor film** in the method of manufacturing a semiconductor device according to the sixth aspect.

Brief Summary Text - BSTX (46):

In the manufacturing method according to the seventh aspect, a bird's beak

largely grows due to the polycrystalline **semiconductor film** included in the multilayer film, whereby stress is further effectively relaxed.

Brief Summary Text - BSTX (47):

According to an eighth aspect of the present invention, the step (d) further includes a step (d-1) of executing etching through the patterned **nitride semiconductor film employed as a mask** thereby selectively **removing** a portion immediately under the **opening** until a groove shallower than the trench is formed in the semiconductor substrate in the method of manufacturing a semiconductor device according to the sixth or seventh aspect.

Brief Summary Text - BSTX (53):

A method of manufacturing a semiconductor device according to an eleventh aspect of the present invention comprises steps of (a) preparing a semiconductor substrate having a main surface, (b) forming a multilayer film including an oxide **semiconductor film,** an oxynitride **semiconductor film** or an oxyhalide **semiconductor film** coming into contact therewith and a nitride **semiconductor film** located thereon on the main surface of the semiconductor substrate, (c) patterning the nitride **semiconductor film** thereby selectively forming an **opening** having a shape separating the main surface into a plurality of regions in the nitride **semiconductor film,** (d) executing etching through the patterned **nitride semiconductor film employed as a mask** for selectively **removing** a portion immediately under the **opening** thereby forming a trench in a portion of the semiconductor substrate immediately under the **opening,** (e) forming an inner wall insulator film including an oxide **semiconductor film** coming into contact with an inner wall of the trench on the inner wall, (f) filling the trench with an insulation after the step (e), (g) **removing** the multilayer film at least after the step (e), and (h) forming a component of a semiconductor element in each of the plurality of regions separated from each other by the trench in the main surface of the semiconductor substrate.

Brief Summary Text - BSTX (54):

In the manufacturing method according to the eleventh aspect, the multilayer film includes the oxynitride **semiconductor film** or the oxyhalide **semiconductor film** coming into contact with the oxide **semiconductor film,** whereby diffusion of an oxidant is suppressed on the side wall of a portion under the nitride **semiconductor film** of the multilayer film in the step of forming the inner wall insulator film. Thus, it is possible to suppress excessive growth of a bird's beak following formation of the inner wall insulator film, for suppressing reduction of an active region. Further, an oxynitride semiconductor part in the bird's beak is left unremoved in the step of removing the multilayer film, whereby no depressed part is formed despite the small thickness of the bird's

beak.

Brief Summary Text - BSTX (55):

According to a twelfth aspect of the present invention, the step (g) includes a step (g-1) of removing the nitride **semiconductor film** included in the multilayer film between the steps (e) and (f), and the method further comprises a step (i) of forming an insulator film including a nitride **semiconductor film** on an exposed surface between the steps (g-1) and (f) in the method of manufacturing a semiconductor device according to the eleventh aspect.

Brief Summary Text - BSTX (56):

In the manufacturing method according to the twelfth aspect, the nitride **semiconductor film** has a function of suppressing diffusion of an oxidant, thereby suppressing oxidation on the interface between the semiconductor substrate and the element isolation structure in thermal oxidation performed in the step of forming the element of the semiconductor element or the like. Thus, occurrence of oxidationinductive defects is suppressed.

Brief Summary Text - BSTX (57):

According to a thirteenth aspect of the present invention, the insulator film further includes a nitride **semiconductor film** in the method of manufacturing a semiconductor device according to the twelfth aspect.

Brief Summary Text - BSTX (58):

According to a fourteenth aspect of the present invention, the step (g) includes a step (g-1) of removing the nitride **semiconductor film** included in the multilayer film between the steps (e) and (f), and the method further comprising a step (i) of forming an insulator film including an oxynitride **semiconductor film** on an exposed surface between the steps (g-1) and (f) in the method of manufacturing a semiconductor device according to the eleventh aspect.

Brief Summary Text - BSTX (59):

In the manufacturing method according to the fourteenth aspect, the oxynitride **semiconductor film** has a function of suppressing diffusion of an oxidant, thereby suppressing oxidation on the interface between the semiconductor substrate and the element isolation structure in thermal oxidation performed in the step of forming the element of the semiconductor element or the like. Thus, occurrence of oxidationinductive defects is suppressed. Further, the coefficient of volume expansion of the oxynitride semiconductor is approximate to that of the semiconductor, whereby stress is